CLAIMS

1. A process comprising:

hydroformylating at least one olefin with carbon monoxide and hydrogen in the presence of a hydroformylation catalyst to form a hydroformylation product, wherein the hydroformylation takes place in a series of at least two hydroformylation reactors;

recycling unreacted gases to at least the hydroformylation reactor in the second position, wherein the unreacted gases originate from the hydroformylation step or from a subsequent hydrogenation step;

passing the hydroformylation product to a high pressure separator and separating an offgas having a concentration of carbon monoxide such that the partial pressure of carbon monoxide in the offgas is above 75 barg.

2. The process according to claim 1 comprising

removing catalyst residues from the hydroformylation product to form a substantially catalyst-free hydroformylation product, and

subsequently hydrogenating the substantially catalyst-free hydroformylation product, wherein the unreacted gases passed to at least the hydroformylation reactor in the second position comprise unreacted hydrogen from the hydrogenation step.

3. The process according to claim 2 wherein the unreacted gases that are recycled comprise unreacted gases from the hydroformylation step and unreacted hydrogen from the hydrogenation step.

4. The process according to claim 1 wherein the hydroformylation process is selected from the group consisting of a high pressure hydroformylation process and a medium pressure hydroformylation process, wherein feed to the first hydroformylation reactor; comprises a mixture of:

i. one or more olefins;

ii. carbon monoxide;

iii. hydrogen; and

iv. recycle gases comprising unreacted gas from the one more hydroformylation reactors;

and the feed to the hydroformylation reactor in the second position comprises a mixture of the reaction product from the first reactor and recycle gases comprising unreacted gas from one or more of the hydroformylation reactors.

5. The process according to claim 4 comprising hydroformylating the olefin(s) in a series of at least three reactors and the feed to the reactor in the third position comprises the reaction product from the reactor in the second position and recycle gases from one or more of the hydroformylation reaction.

6. The process according to claim 4 comprising hydroformylating the olefin(s) in a series of four reactors and the feed to the reactor in the fourth position consists of the reaction product from the reactor in the third position.

7. The process according to claim 1 comprising hydroformulating the olefin(s) at a pressure of from 50 to 350 barg.

8. The process according to claim 1 comprising hydroformylating the olefin(s) at a temperature of from 120 to 185°C.

9. The process according to claim 1 wherein the hydroformylation catalyst is absorbed in the olefin feed.

10. The process according to claim 1 wherein the hydroformylation catalyst comprises a rhodium catalyst or cobalt catalyst.

11. The process according to claim 10 wherein the catalyst is a cobalt catalyst and the molar ratio of hydrogen to carbon monoxide used for hydroformylation is about 1.3:1.

12. The process according to claim 10 wherein the catalyst is a cobalt catalyst and wherein the process further comprises contacting sodium hydroxide soda or sodium carbonate with the hydroformylation reaction product in a decobalter vessel.

13. The process according to claim 12 comprising contacting a stoichiometric excess of 100 to 200% of sodium hydroxide soda or sodium carbonate with the hydroformylation product.

14. The process according to claim 12 wherein the decobalter vessel is operated at a temperature in the range 155-165°C.

15. The process according to claim 10 wherein the catalyst is a cobalt catalyst and the process furthercomprises removing the cobalt catalyst from the hydroformulation reaction product by contacting the hydroformylation reaction product with an acid and/or an oxidant.

16. The process according to claim 15 wherein the acid comprises formic acid or acetic acid.

17. The process according to claim 15 wherein the oxidant t comprises oxygen, an oxygen containing gas, air and/or a combination thereof.

18. The process according to claim 1 wherein the partial pressure of carbon monoxide is above 77 barg.

19. The process according to claim 18 wherein the high pressure separator operates at a pressure of at least 250 barg.

20. The process according to claim 18 comprising passing at least a portion of the offgas from the high pressure separator to an offgas recycle compressor system.

21. The process according to claim 18 comprising feeding the liquid left in the high pressure separator to an intermediate pressure separator and reducing the pressure to a level at which gases entrained with the liquid from the high pressure separator are released as an intermediate pressure offgas.

22. The process according to claim 21 wherein the pressure in the intermediate pressure separator is between 80 and 120 barg.

23. The process according to claim 21 wherein at least a portion of the intermediate pressure offgas is sent to an offgas recycle compressor system for subsequent recycle.

24. The process according to claim 1 wherein the recycling step employs a compressor system comprising a series of gas compressor stages.

25. The process according to claim 24 wherein the recycle compressor system comprises three gas compressor stages in series.

26. The process according to claim 25 comprising feeding high pressure offgas and intermediate pressure offgas from the hydroformylation step (and optionally unreacted gas from the hydrogenation stage) to the first compressor stage, which operates at a suction pressure between 50 and 60 barg.

27. The process according to claim 26 comprising feeding the gas mixture discharged from the first compressor stage, optionally with intermediate pressure offgas, to the second compressor stage and increasing the pressure to within the range of 140 to 180 barg.

28. The process according to claim 27 comprising feeding the gas mixture discharged from the second compressor stage, optionally with high pressure offgas, to the third compressor stage.

29. The process according to claim 1 wherein the hydroformylation reactors and any further processing equipment in contact with the hydroformylation product are constructed from duplex stainless steel.

30. An apparatus for the production of alcohols from an olefin, comprising a series of at least two hydroformylation reactors, a catalyst removal system in fluid communication with the hydroformylation reactors, the catalyst removal system adapted to remove catalyst residues from the hydroformylation product, a hydrogenation reactor in fluid communication with the catalyst removal system, and a recycle line in fluid communication with the hydrogenation reactor and at least the second hydroformylation reactor so that unreacted hydrogen from the hydrogenation reactor may be recycled to at least the second hydroformylation reactor.

31. The apparatus according to claim 30 wherein the recycle line is adapted to receive and recycle unreacted gases from one or more of the hydroformylation reactors.

32. The apparatus according to claim 30 wherein the hydroformylation reactors and any further processing equipment in contact with the hydroformylation product are constructed from duplex stainless steel.